Operative Techniques in
Thoracic and
Cardiovascular Surgery

Aortic Valve Repair in Children, Including Pericardial Patch Reconstruction

Aditya K. Kaza, MD,* and John A. Hawkins, MD†

Aortic valve repair is a technique that is gaining popularity in children because of the lack of an ideal valve substitute in this patient population. It has the advantage of preserving the native valve and the potential for growth. As experience with the Ross procedure is gained, we note that reoperation on children who have undergone a Ross procedure is inevitable, and thus, aortic valve repair has become more attractive. Frequently repair can put off the need for valve replacement until full growth is achieved and more options with prosthetic valves are available.

*Section of Pediatric Cardiothoracic Surgery, Department of Surgery, University of Utah School of Medicine and Primary Children's Medical Center, Salt Lake City, Utah.

†Division of Cardiothoracic Surgery, Department of Surgery, University of Utah School of Medicine and Primary Children's Medical Center, Salt Lake City, Utah.

Address reprint requests to John A. Hawkins, MD, Professor and Chief, Division of Cardiothoracic Surgery, Department of Surgery, University of Utah School of Medicine and Primary Children's Medical Center, 100 N. Mario Capecchi Drive, Suite 2800, Salt Lake City, UT 84113. E-mail: john.hawkins@hsc.utah.edu

The child with aortic valve disease should always be approached with the mindset toward repair rather than replacement. With this in mind, our approach to evaluating the repairability of the valve involves thorough preoperative echocardiography as well as newer techniques of 3-dimensional echocardiography, to get a good assessment of where the problem is occurring. The annulus size is evaluated and the coaptation of the leaflets can be examined using these echocardiographic techniques. Once the aorta is open, the aortic valve is evaluated at the 3 following levels: the annulus, the leaflets, and the sinotubular junction. The annulus should be evaluated for size using established tables for normal. The leaflets should be carefully examined for size, pliability, and coaptation. In addition, the leaflets need to be evaluated for areas of leaflet deficiency, thickness of the leading edges, and the degree of commissural support. The sinotubular junction should also be evaluated for size. The repair should then be tailored toward normalizing, as much as possible, all 3 of these levels of the aortic valve mechanism.

1522-2942/09/$-see front matter
doi:10.1053/j.optechstcvs.2009.08.001

Operative Technique

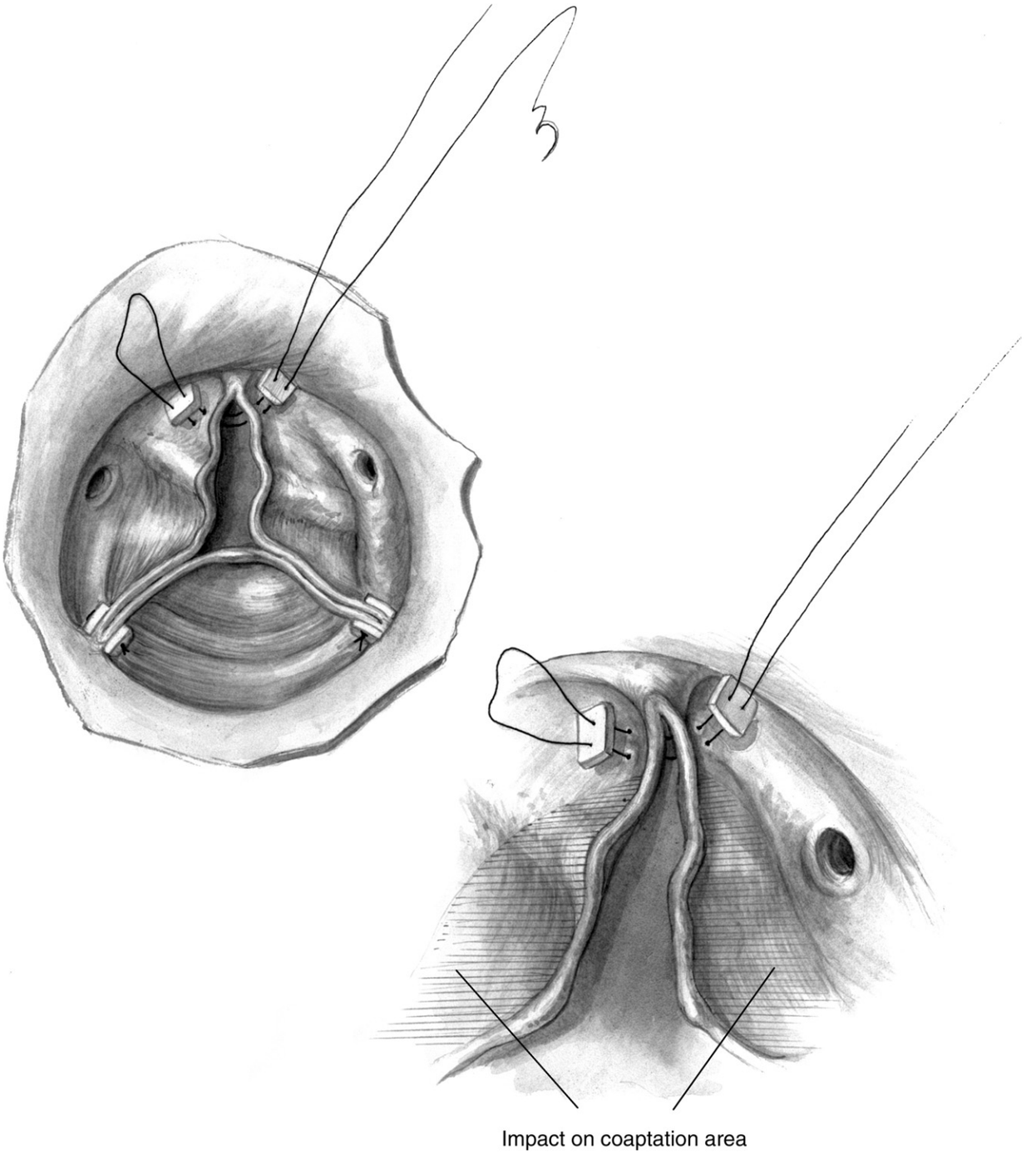

Figure 1 This figure depicts the technique commonly referred to as aortic commissuroplasty. It is a very simple technique that consists of a horizontal mattress suture taken at each commissure. Pledgets are typically made of pericardium or, in some circumstances, Teflon felt material. The suture is typically 5-0 or 6-0, depending on the child's size and the individual situation. Commissuroplasty is used in situations in which the preoperative echocardiogram demonstrates central regurgitation and the annulus size is mildly dilated (only 2-3 mm above expected). Usually commissuroplasty sutures are placed at all 3 commissures. The commissuroplasty improves coaptation all along the semilunar valve coaptation line and reduces the annulus size by only 1 to 3 mm.[1] The lower the sutures are placed below the apex of the commissure; the greater the increase in coaptation, the more the annulus size is reduced. This technique also is frequently combined with other techniques that involve direct cusp repair to help improve coaptation and the overall repair.

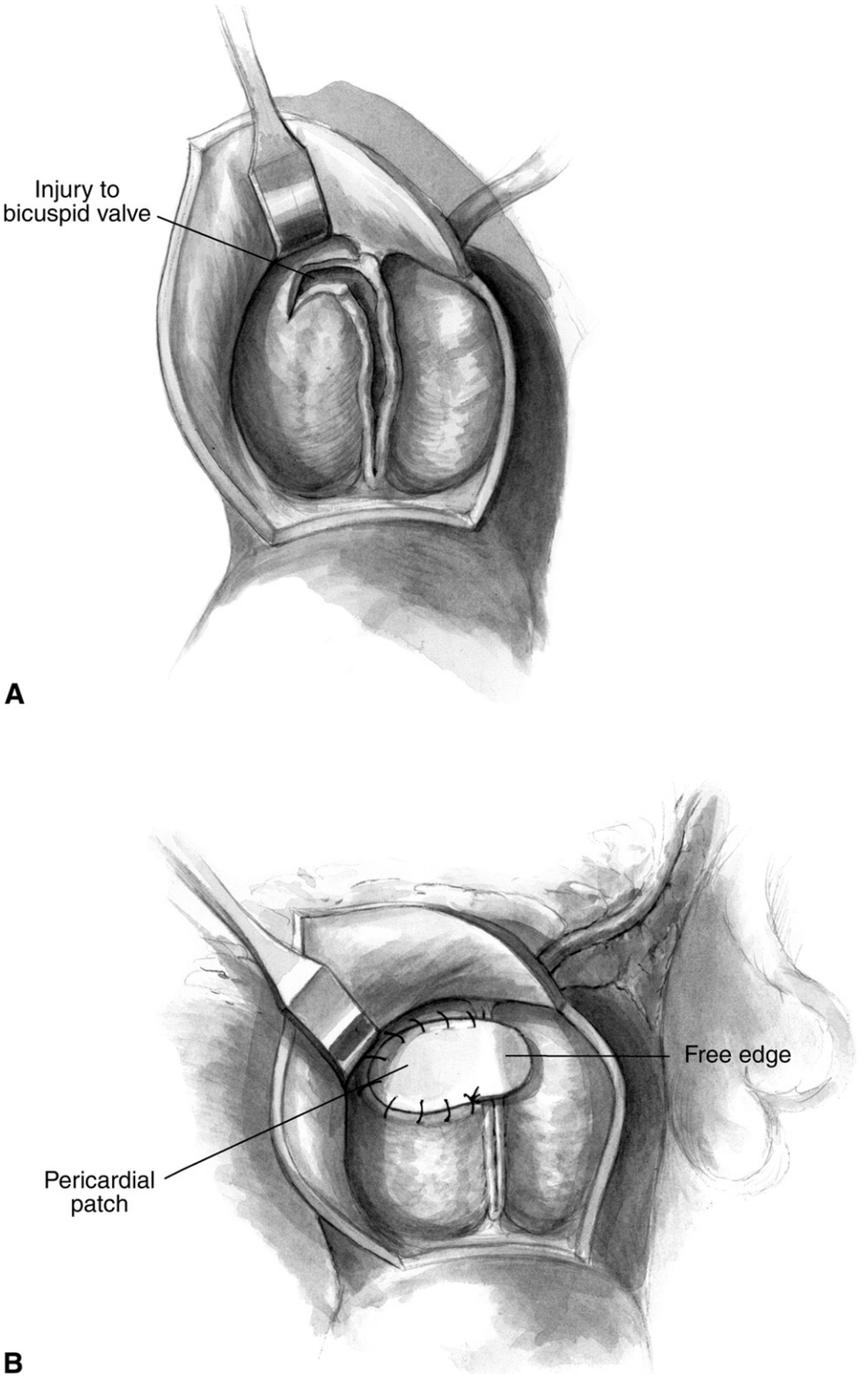

Figure 2 This figure depicts the typical findings in a child with aortic stenosis who has previously undergone balloon aortic valvulotomy and is suffering from moderate to severe aortic insufficiency. The pathologic problem from the surgeon's view is shown in (A) with a linear tear of the anterior leftward leaflet immediately underneath the right coronary artery ostium. This tear typically involves dehiscence right at the junction of the leaflet with the annulus and goes leftward, involving up to 1/3 to 1/2 of the leaflet. The torn portion of leaflet typically prolapses into the left ventricular outflow tract during diastole and is the source of the aortic valve insufficiency. If the time elapsed between the balloon valvuloplasty and the operation is more than a few months, there can be retraction of the prolapsing leaflet and a large gap between the remaining leaflet and the annulus. In this case, the technique of Bacha is usually used, in which a small piece of pericardium is used to "fill in" the gap between the annulus and the remaining leaflet.[2] This is done with 7-0 or 6-0 polypropylene in a continuous over and over running suture. It is necessary to make sure good bites are made at the annulus, because this becomes the hinge point of the pericardial portion of the new repaired valve. It is usually best to leave this pericardium a little long so that the free edge "hangs over" the coaptation point as shown in (B). This results in the best relief from insufficiency. Typically the pericardium is harvested and thinned of extra tissue and fat as much as possible to leave relatively thin pericardium. This is then clipped to a piece of sterile cardboard and treated with 0.6% glutaraldehyde for 5 minutes. Although 5 minutes is somewhat arbitrary, it seems to be the best time to allow some stiffening of the pericardium for durability, but not too much, so as to leave it pliable.

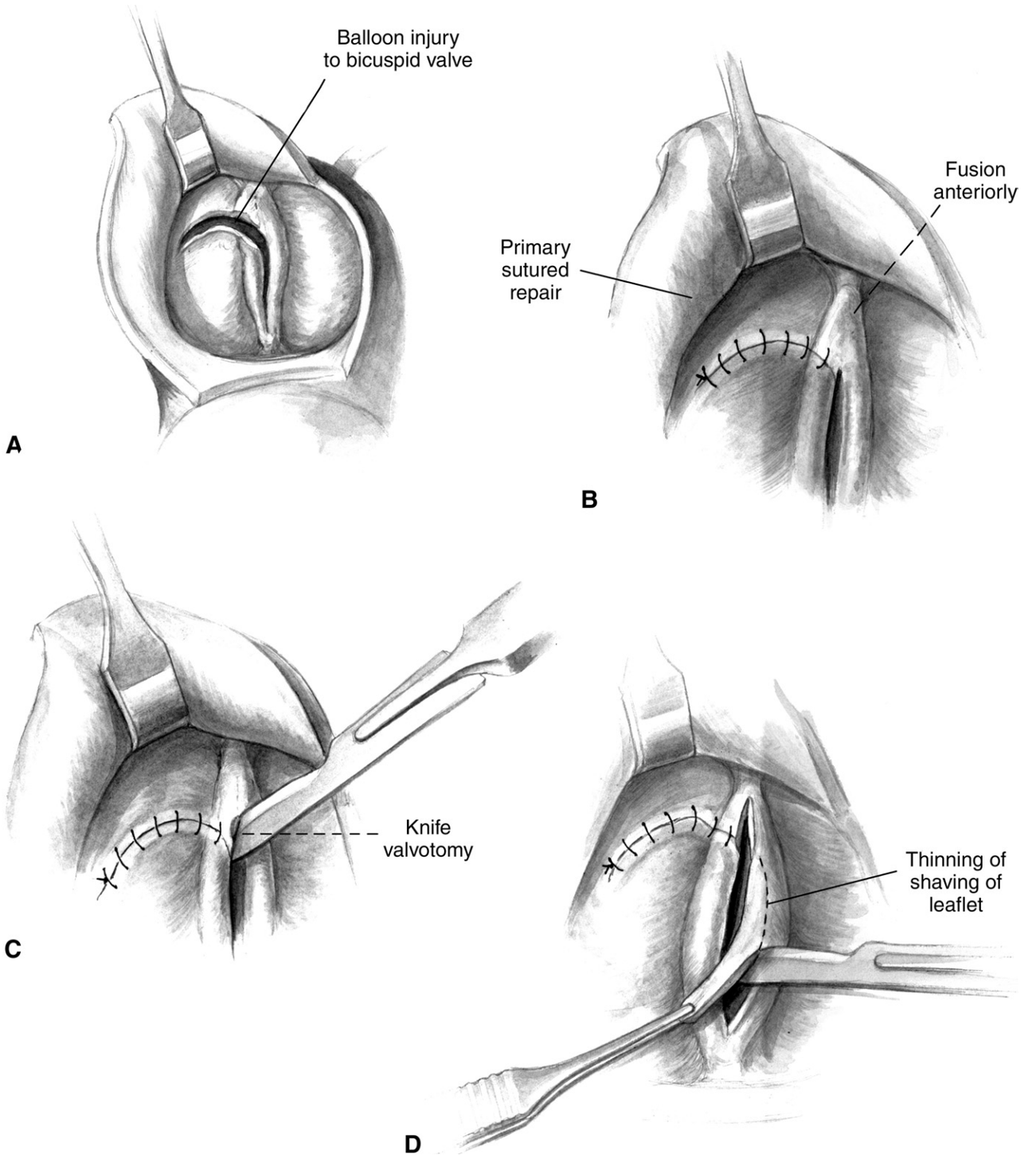

Figure 3 This figure depicts another approach to repair of aortic valve insufficiency following balloon valvulotomy. Again, the pathologic condition demonstrates dehiscence or tearing of the left anterior cusp of the bicuspid valve from the anterior commissure counterclockwise along the annulus (A). This is usually underneath the right coronary ostium. This results in prolapse of the anterior portion of the torn leaflet and severe aortic valve insufficiency. If the time elapsed between the balloon valvulotomy and the need for surgical intervention is relatively short (<1 year), a different approach than that taken in Figure 2 is used. In this instance, the leaflet has not had a lot of time to retract and direct resuturing can be done. In this technique, the torn leaflet is sutured with interrupted 6-0 or 7-0 polypropylene sutures right back to the annulus where it was detached (B). This basically re-creates a bicuspid, stenotic aortic valve, much like the original valve. A traditional valvotomy is then done anteriorly (or posteriorly, if necessary) using a 15-blade or coronary Beaver blade (C). This is usually not sufficient alone, and frequently sharp debridement or "delamination" can be done to thin out the valve on the ventricular surface of the valve (D). One can also thin out the valve in the area of the raphe representing the fusion of the left and right coronary cusps, but care should be exercised so as not to perforate the valve in this area. All of these efforts to thin the valve leaflet help with cusp pliability and with reducing postoperative gradient. This technique is especially useful in the child who has undergone a balloon aortic valvulotomy and is ill in severe heart failure from acute aortic insufficiency. It seems to have good long-term results in this situation.[4]

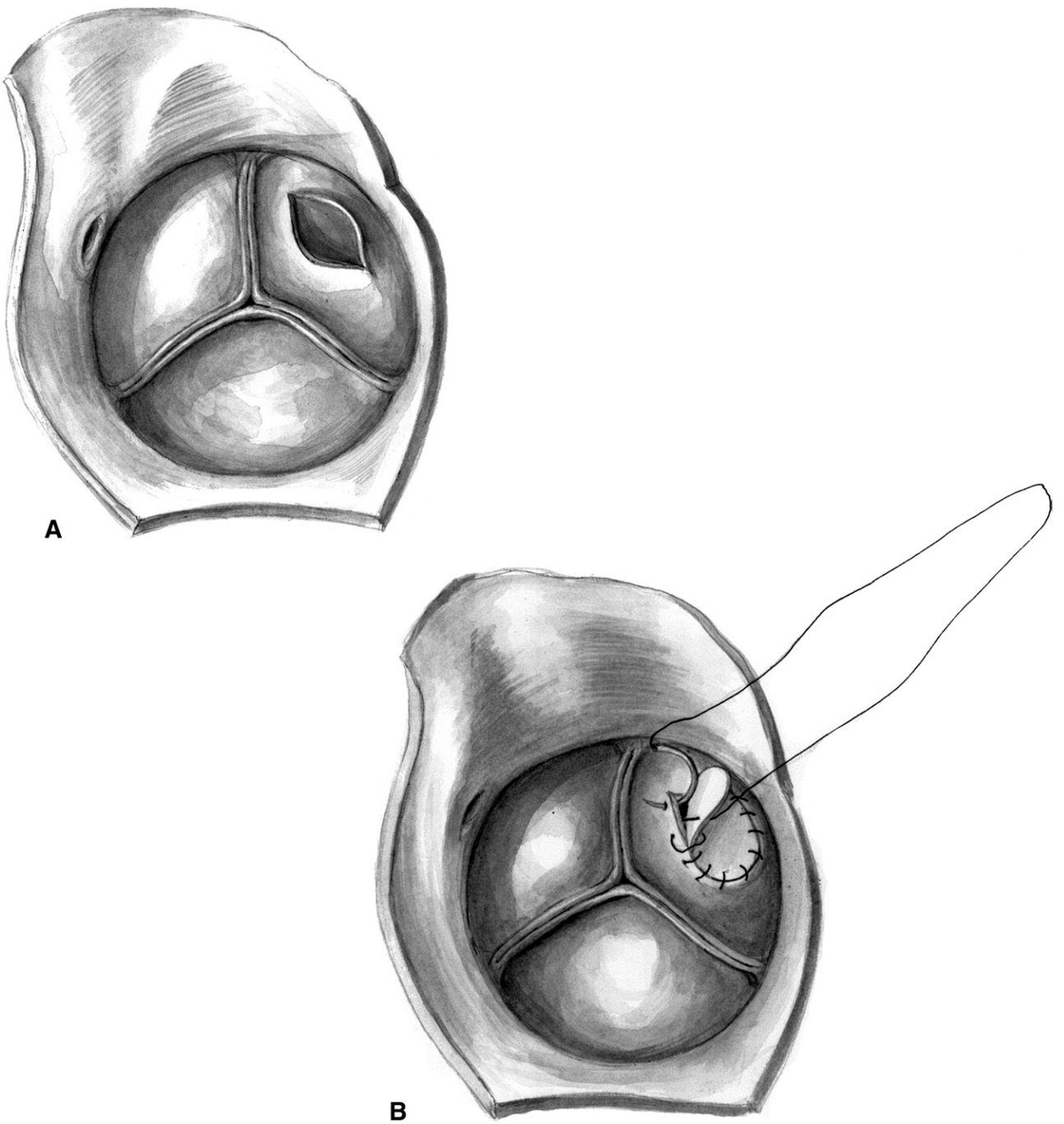

Figure 4 This figure demonstrates the aortic insufficiency situation that one typically sees following a bout of endocarditis, after cardiac catheterization where a wire was passed retrograde across the aortic valve, or in someone who has previously had a subaortic membrane that required "peeling" or dissection off the underside of the aortic valve, resulting in leaflet perforation (A). This is usually very localized and appears on echocardiography to be coming not from the central coaptation point but from a point closer to the annulus. This is among the easiest of aortic insufficiency subsets to repair. This is typically repaired with glutaraldehyde-treated native pericardium prepared as previously described. Polypropylene suture of 6-0 or 7-0 is used to suture the appropriate sized patch directly to the defect (B). Typically when the aortic insufficiency is longstanding, the edges of the defect are quite fibrous and it is easy to get a strong suture line. This same technique can be used for holes in other areas of the leaflet, such as close to the commissure or even a missing portion in the central free edge of a leaflet. Other materials such as Dacron or Gore-Tex are not used, because they are too stiff to allow good function of the thin, pliable semilunar valve.

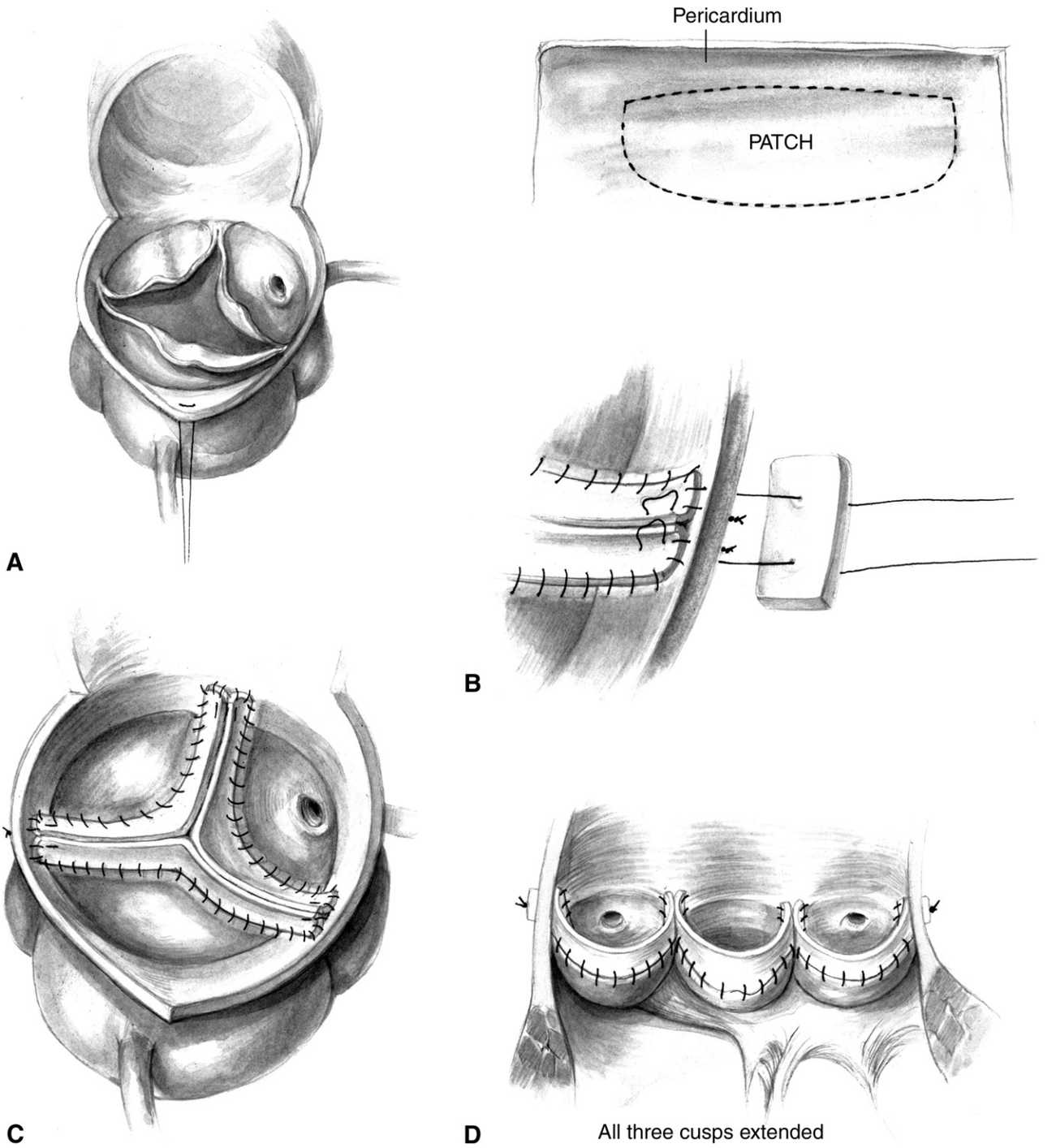

Figure 5 This figure depicts the pericardial patch cusp augmentation technique. Typically this is used in those instances in which the aortic insufficiency is due to severe central coaptation issues, such as those seen with rheumatic heart disease. In these cases each of the 3 leaflets is small and the surface area for coaptation is minimal, as shown in (A). Good-quality pericardium is needed and is prepared with 0.6% glutaraldehyde for 5 minutes and stored in saline. For the situation depicted in this figure, augmentation of all 3 cusps is necessary. This will mean cutting 3 separate patches shaped as shown in the inset. This is done by estimating how much additional cusp will be needed and tailoring the pericardial patch to fit the child's native existing leaflet tissue. This patch is then sutured in place to the free edge of the existing leaflet beginning in the center and going peripherally toward the commissures using 6-0 polypropylene suture. For larger children approaching adult size, 5-0 polypropylene suture may be more appropriate. It is important to carry the suture line 2 or 3 stitches above the top of the commissure to ensure competency centrally and support of the valve repair (B, C). Once this suture line is finished, the sutures are passed outside the aorta and tied over a pledget. This is reinforced at the top of each commissure with a single pericardial pledgetted suture of 6-0 polypropylene suture (B). Some trimming of the pericardial patch along the free edge may be necessary once the suture lines are finished to ensure the proper leaflet size and central coaptation (D).

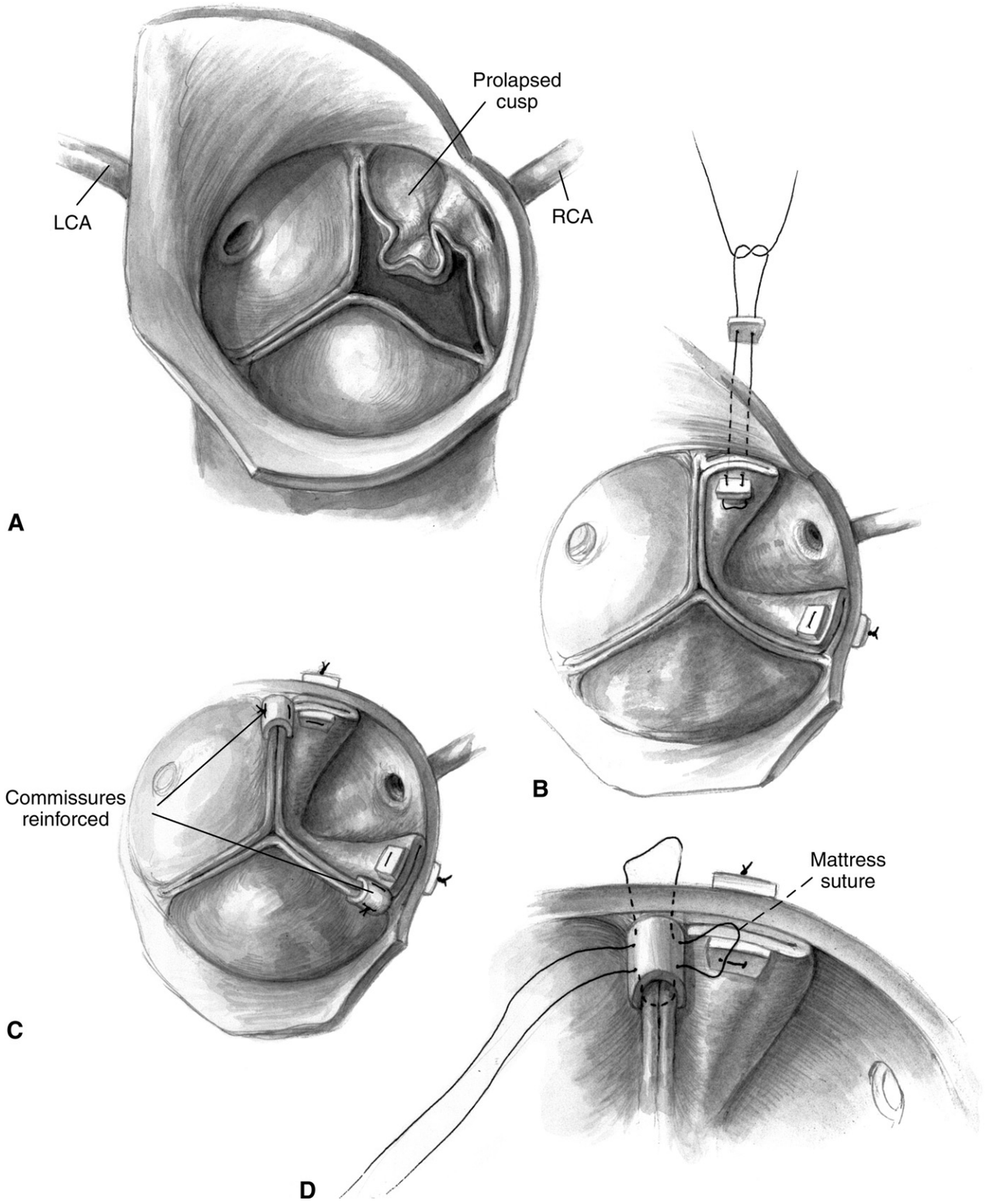

Figure 6 This figure depicts the repair of aortic valve insufficiency that originates from a prolapsing, redundant valve leaflet that was initially reported by Trusler and coworkers.[3] The pathologic condition shown illustrates a redundant leaflet that has had elongation of its free edge from chronic prolapse, such as that seen in longstanding, unrepaired outlet-type ventricular septal defect (A). In this technique it is important to line up the central node of Aranti with the central nodes on the other 2 leaflets using a fine suture and then to plicate the redundant leaflet at each involved commissure. This involves plication of the redundant leaflet at each commissure using a pericardial pledgetted 5-0 polypropylene suture in horizontal mattress fashion passed from inside the aortic sinus to outside the aorta (B). Once this has been done, it is reinforced with small pericardial "hoods" placed at each commissure to relieve the stress point of the reconstructed commissure (C, D). LCA = left coronary artery; RCA = right coronary artery.

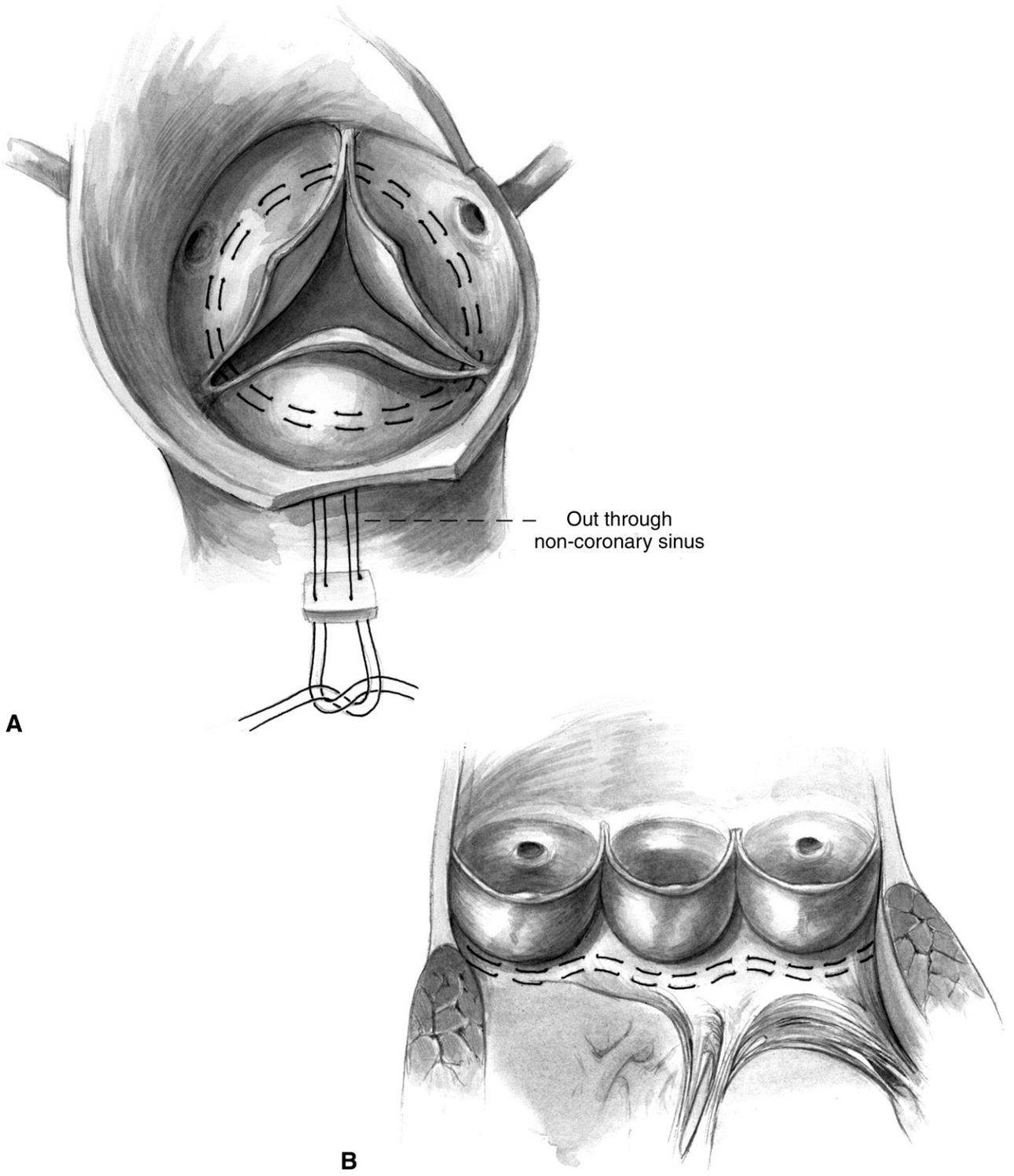

Figure 7 This figure depicts the technique of aortic valve annuloplasty. This technique is used when the leaflets appear to be sufficient in terms of cusp area and size, but there remains a central coaptation problem because of annular dilation. This technique is particularly useful when there is central aortic insufficiency following a Ross procedure, or in some cases of severe annular dilation due to connective tissue disease. This technique is applicable when the annular dilation is more than 2 to 3 mm larger than predicted for the patient's size. A double suture line is started from outside the aorta in the noncoronary sinus and then proceeds in the annular or immediately subannular tissue using a circumferential suture of 4-0 or 5-0 polypropylene suture (A, B). This suture is then tied down using a pledget outside the aorta with a hegar or valve sizer placed in the aortic annulus that is the size of the predicted annulus for the patient's size and surface area. In those cases, when this technique is used in a small child, in which more annular growth is anticipated, we have used absorbable 4-0 or 5-0 polydiaxanone suture in the hope of reducing the annular size initially and then having suture resorption take place and allow later growth.

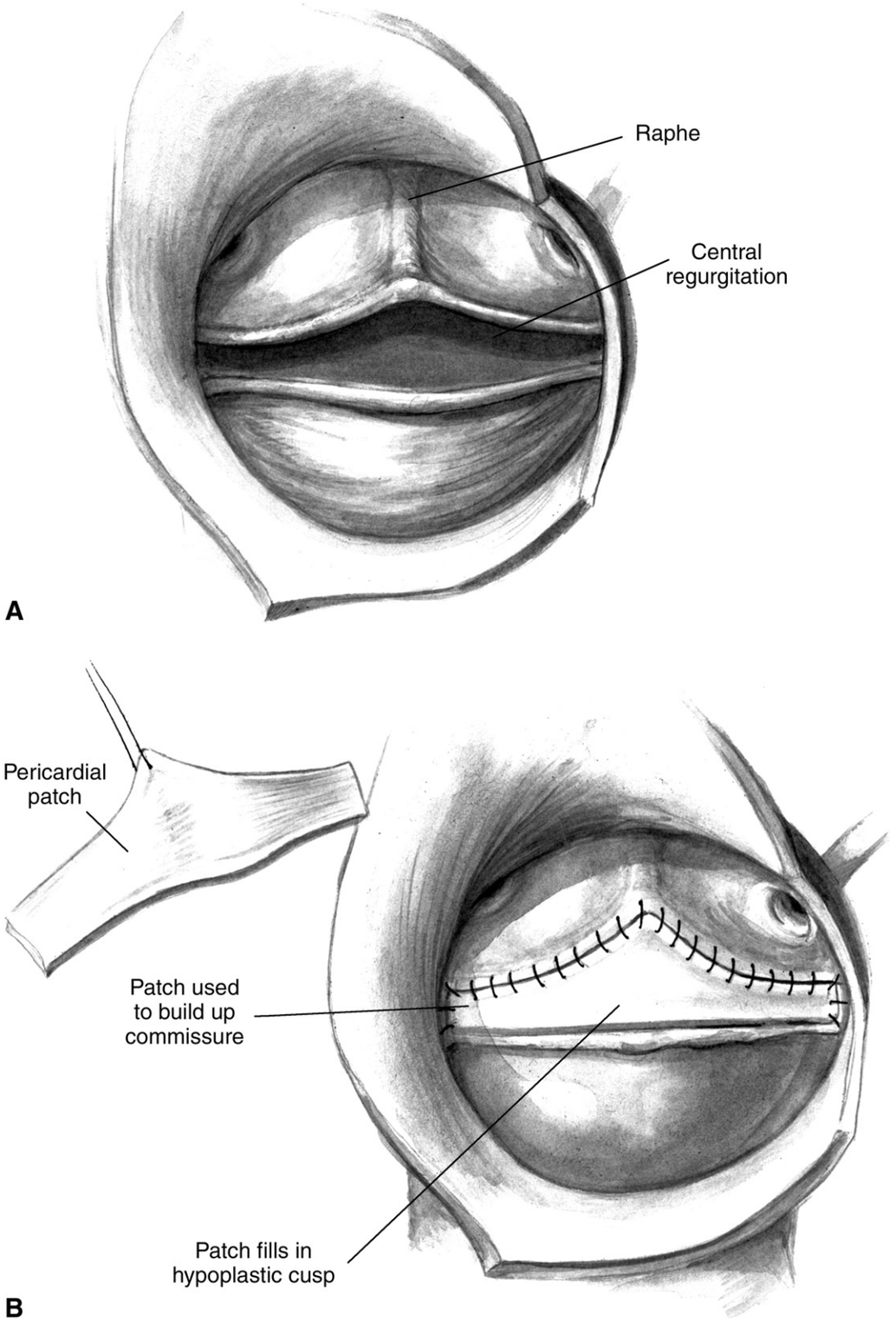

Figure 8 This figure depicts the technique of partial pericardial cusp augmentation. It is used in situations where there may be only 1 cusp that appears to be deficient (A). This figure depicts a bicuspid valve with a thickened and foreshortened fused leaflet. There is central insufficiency because the bicuspid valve simply cannot coapt with the more normal noncoronary cusp leaflet. This may also occur in a trileaflet valve in which 2 leaflets may be normal and 1 leaflet is either deficient in size or damaged. In this case we have elected to just augment the deficient leaflet and leave the normal leaflets alone. This involves, again, harvesting a thin piece of good pericardium and treating it with 0.6% glutaraldehyde for 5 minutes. The pericardium is then cut to simply "fill in" the deficient leaflet centrally. Typically this patch is sewn in place with 6-0 continuous polypropylene beginning centrally and carrying the suture line peripherally toward the commissure. In contrast to the technique in which all 3 cusps are augmented, this single-cusp augmentation does not need to be carried up high on the commissure, but simply terminated at the top of the native commissure and leaflet tissue, and the suture tied (B). The patch can be trimmed once it is in place to fashion the leaflet to the proper size and to enhance central coaptation.

Conclusions

We have used these repair techniques to repair the aortic valve or the neo-aortic valve for aortic insufficiency in over 80% of children referred for aortic insufficiency in recent years.[5] In addition, we have also used aortic valve repair techniques extensively in the repair of the aortic valve in truncus arteriosus. Frequently the individual child may require 2 or 3 of these techniques to accomplish repair and an acceptable and competent valve. The techniques and their application must be individualized to the child and his particular pathologic condition. This approach of repair has resulted in about 70% of the children being free of any reoperation at 5 years, and about 60% being free of reoperation at 10 years. Perhaps even more important, over 80% of our patients were free of aortic valve replacement at 5 years and over 70% were free of aortic valve replacement at 10 years. The functional results in our patients have shown that, in 37 patients who had not required reoperation, residual aortic insufficiency was traced to 1+ in 23, 1 to 2+ in 12, 2 to 3+ in 1, and 3 to 4+ in 1 at echocardiography 5 years following operation.[5]

References

1. Fraser CD, Cosgrove DM: Aortic valve reparative procedures. Adv Card Surg 7:65-86, 1996
2. Bacha EA, McElhinney DB, Guleserian KJ, et al: Surgical aortic valvuloplasty in children and adolescents with aortic regurgitation: Acute and intermediate effects on aortic valve function and left ventricular dimensions. J Thorac Cardiovasc Surg 135:552z-559, 2008
3. Trusler GA, Moes CA, Kidd BS: Repair of ventricular septal defect with aortic insufficiency. J Thorac Cardiovasc Surg 66:394-403, 1973
4. Hawkins JA, Minich LL, Shaddy RE, et al: Aortic valve repair and replacement after balloon aortic vavluloplasty in children. Ann Thorac Surg 61:1355-1358, 1996
5. Hawkins JA, Kouretas PC, Williams RV, et al: Intermediate-term results of repair for aortic, neo-aortic, and truncal valve insufficiency in children. J Thorac Cardiovasc Surg 133:1311-1317, 2007